Economic Trends of Gold, Silver, Copper, and Molybdenum in the United States/World and the Effects on Domestic and Foreign Policy in the Future

A Thesis

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by

David J. Sugar

Adviser

Douglas E. Pride

ABSTRACT

Gold, silver, copper, and molybdenum are four metals that play an important part in the United States and world economies. Production, price, imports, and exports must be studied in order to increase our understanding of these metals. Projected domestic reserves in copper and molybdenum are predicted to have the potential to supply all domestic needs for the two metals in the year 2000, whereas domestic reserves of gold and silver probably will not be sufficient. Production of gold and silver has kept up with demand, while the demand for the base metals copper and molybdenum has stagnated as production exceeds demand. The price of the four metals are highly unpredictable for silver and gold in the short term, and copper and molybdenum are predictable. Long term predictions for the four metals indicate that demand will increase along with price.

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INTRODUCTION

Purpose and Significance

The mining of metals is essential to the United States and world economies. To maintain a healthy metals industry it is important that we understand something about the occurrence, obtainability, and uses of metals such as gold, silver, copper, and molybdenum. This is not easy to do because of the complexity involved in the economics of metals. This report tries to increase understanding of metals to our economy today, and in the future.

The precious metals gold and silver and the base metals copper and molybdenum are discussed in this report. These four metals were chosen because of their importance in our society and the potential impact they have on our economy. Many factors contribute to changes in the economics of metals, and often it is hard to predict their influence on metals.

GOLD

Characteristics of Gold

Gold occurs naturally as a single stable isotope, with an atomic number of 79, and an atomic weight of 197. Its melting point is (1063 degrees C) and its specific gravity is 19.3. Pure gold has a bright yellow color, it is very malleable, highly ductile, very reflective to infrared radiation, and to most of the visible spectrum. Gold alloys readily with common metals, and it has a high electrical and thermal conductivity. Because of its non-reactivity towards most substances, gold will not readily tarnish or corrode.

Gold and other precious metals are measured by the troy system of weights, which is based on the troy ounce of 480 grains, equal to 31.104 grams [Emmons, 1974]. One-tenth of a cubic inch of pure gold weighs about one troy ounce. The terms "karat" and fineness" refer to the purity of gold. The former refers to the weight proportion of pure gold in an alloy, expressed in parts per thousand. The latter is expressed in 24ths, for example, 12K gold is 12/24 or 50 percent pure.

Uses of Gold

The oldest use of gold, in jewelry and art objects, consumes 54 percent of all domestic gold [Lucas, 1985]. Gold makes excellent jewelry. It is nonallergenic for most people, it remains tarnish-free, it is relatively easy to fashion, and it has a bright pleasing color. Industrial uses of gold account for 34 percent of the domestic gold consumed. The most important industrial use is in electronics, especially in circuit boards, connectors, keyboard contactors, and miniaturized circuitry. Modern electronic devices utilize very low voltages and currents that require certain components to remain completely free of corrosion; in addition, the circuitry should remain chemically and metallurgically stable for the life of the device [Butterman, 1980]. Gold-containing brazing alloys are important to the aerospace industry, especially in jet engine assembly. Gold also can be used as a reflector to conserve energy. As a organometallic fluid, gold can be applied on porcelain and glass products for decoration. The dental industry uses about 11 percent of domestic gold. Dental work, such as inlays, crowns, bridges, and orthodontic appliances have been constructed of gold. About one percent of domestic gold is used for investment (gold coins, bars, etc.).

Byproducts and Coproducts of Gold

In many parts of the world a significant amount of gold is recovered in the refining of other metals, particularly copper. In the United States as much as 40 percent of the total gold production has been recovered as a byproduct of base metal mining. In recent years the copper mining industry has been cut back drastically, which in turn has affected gold production. This decline recently has been offset by increased gold mine development and production. Many gold mines produce silver as a coproduct of gold production, and some foreign operations also yield platinum-group metals and uranium.

Gold Technology

The relatively high prices of gold in recent years has encouraged exploration and development of new gold deposits. Improvements in the cyanide process has allowed a highly efficient means of extracting gold from low-grade ores. This improvement is called the heap leaching technique, which involves distributing a weak cyanide solution over the top of an open mound or heap of gold ore and collecting the enriched solution for gold extraction [Butterman, 1980]. Gold extraction procedures are continually being improved to allow for the highest gold yields.

Efforts to reduce the amount of gold used in high technology applications have progressed to the point where there now are platinum/nickel and silver/nickel alloys with comparable characteristics to gold [Hamilton, 1982]. This fact has caused a relative decrease in the amount of gold consumption and it appears that this trend will continue because of the high level of competition in the electronics industry.

Production of Gold

In the last few years the domestic economic and political climate has played a role in directing some mining companies that traditionally were involved only with fuels and other nonmetallic minerals towards precious metals exploration. World mine production in 1984 was estimated at 45 million troy ounces, and the breakdown is given in Table 1. Domestically, mine production from 1980 to 1984 has increased at a rate of about .03 million troy ounces per year [Fig. 1]. This trend should last for a while but eventually will trail off when the gold reserves are depleated to an appreciable extent. The value of 1984 domestic gold mine production was estimated at 840 million dollars [Lucas, 1983].

From 1970 to 1980 [Fig. 1], there was a general decrease in the amount of gold produced in the United States. In the future, however, domestic gold production should grow at about 2 percent annually, to reach 2.5 million ounces by the year 2000 [Lucas, 1985]. It is likely that world production will fall short of filling primary gold demand by about 25 percent by the year 2000 [Butterman, 1980]. A number of factors could effect domestic and world predictions, including the cost of meeting environmental standards; new taxation and leasing measures; difficulty in finding new gold deposits; slower than projected growth of production; and stricter mining laws, creating increased expenses.

Table 1

World Gold Mine Production and Reserve Base For 1984

[Data in million troy ounces of gold content]

Country	Mine Production	Reserve Base
United States	2.30	100
Australia	1.10	30
Canada	2.50	50
Republic of South Africa	22.00	800
Other Market Economy Countries	6.20	210
China	2.00	260
U.S.S.R.	8.60	
Other Centrally Planned Economies	0.30	
World Total	45.00	1,450

[Lucas, 1985]

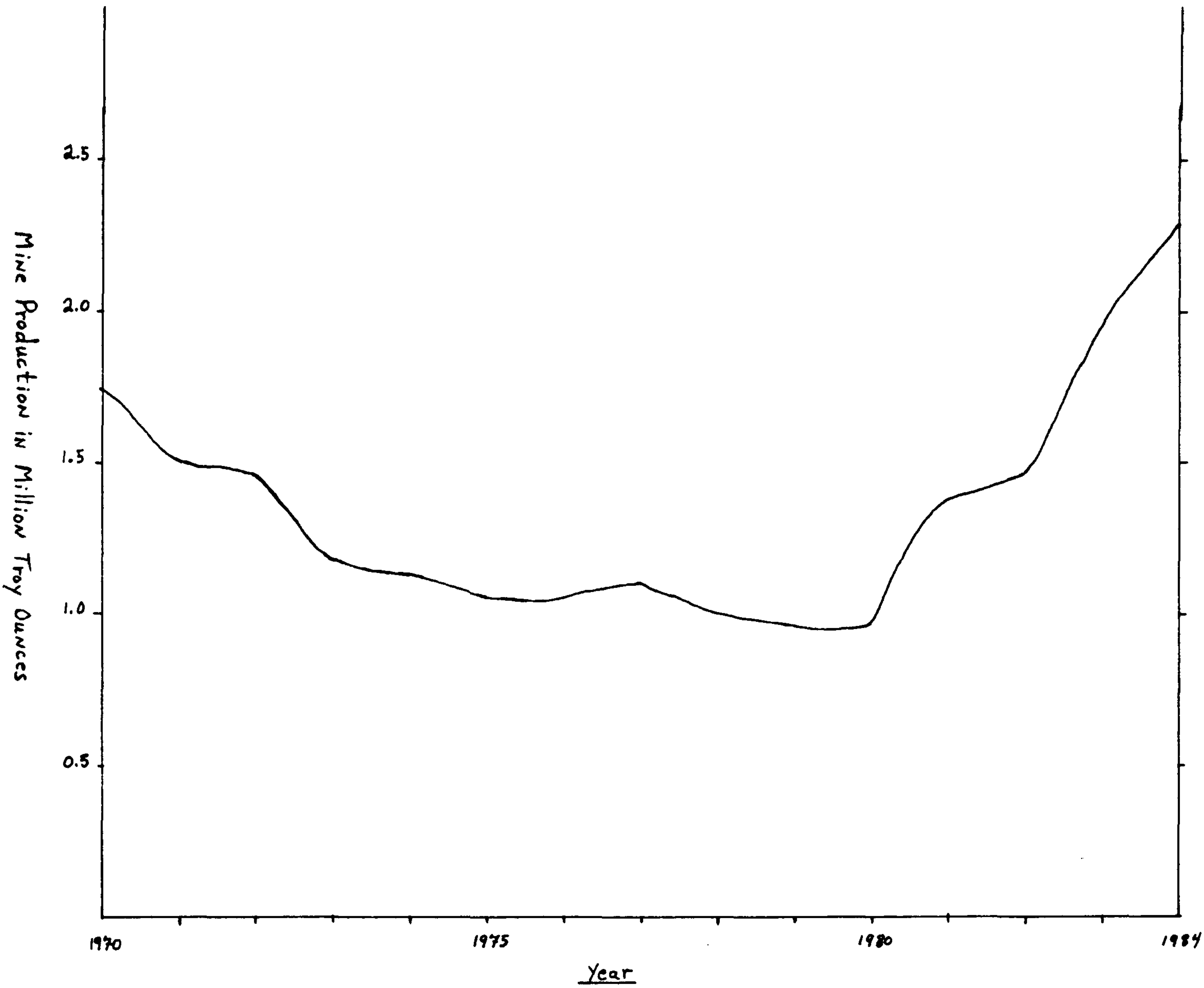

Figure 1 Total United States Gold Mine Production, actual trends, 1970-1984. Data from [Lucas, 1985], [Lucas, 1983].

The amount of gold imported by the United States has changed dramatically over the past 15 years, with a large increase from 1983 to 1984, reflecting an increase in the domestic demand for gold [Fig. 2]. From 1970 to 1974, and from 1981 to 1984, the United States imported more gold than it exported [Fig. 3]. It seems logical to assume that this trend will continue in the future due to increasing domestic gold demand. Increasing gold demand will stimulate development of new gold mining technologies, and new exploration. Gold currently is an economic metal to mine, which is reflected in the present increases in exploration and production. The price of gold is quite variable in the short-term. Changes are not well enough understood by economists to allow for accurate price forecasts, although it does seem accurate to say that the price of gold will increase in the coming years as reserves dwindle [Fig. 4].

Gold Reserves

The reserve base [the identified part of a resource that meets specified minimum physical and chemical criteria related to current mining and production practices, including those for grade, quality, thickness, and depth] is estimated for the world gold reserves in Table 1 [Lucas, 1985]. About 2.1 billion troy ounces of gold are in the world's above-ground stocks as of 1984, and about 2.4 billion ounces of gold still are in the ground [Lucas, 1985].

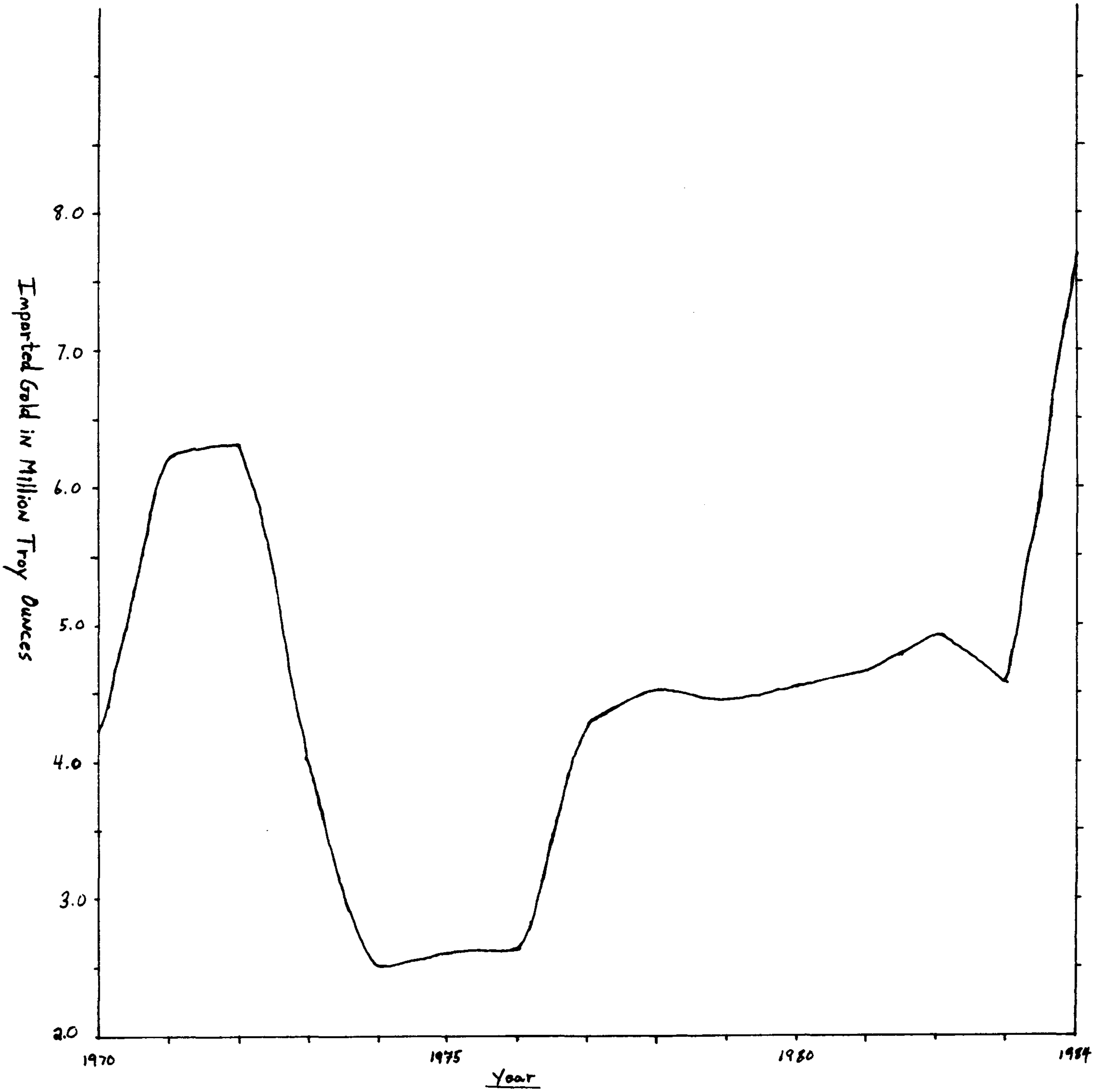

Figure 2. Total United States Imported Gold, actual trends, 1970-1984. Data from [Lucas, 1985], [Lucas, 1983].

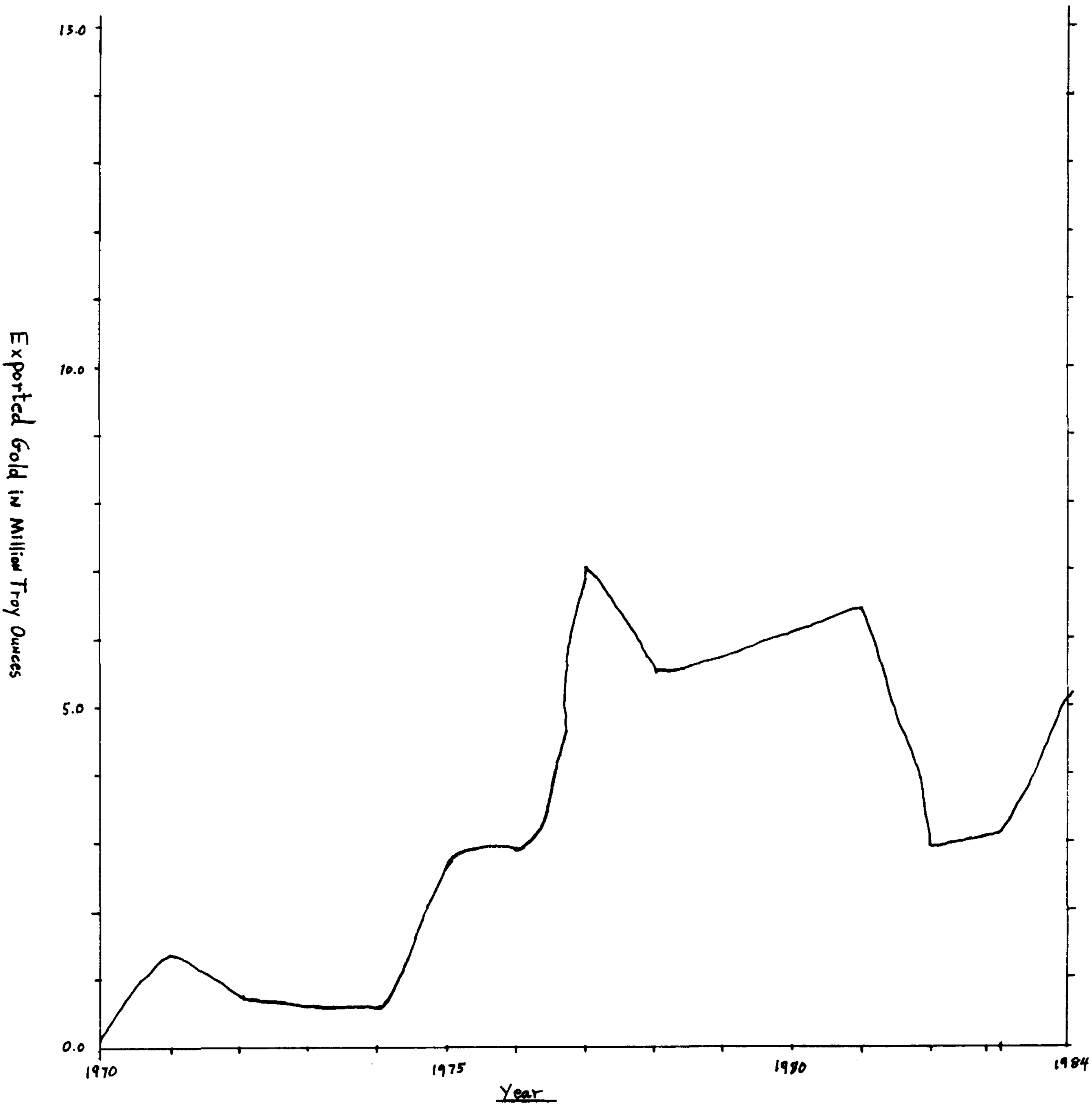

Figure 3. Total United States Exported Gold, actual trends, 1970-1984. Data from [Lucas, 1985], [Lucas, 1983].

The Republic of South Africa has about one-half of the world's supplies, while the United States, Brazil and the U.S.S.R. have about 12 percent each.

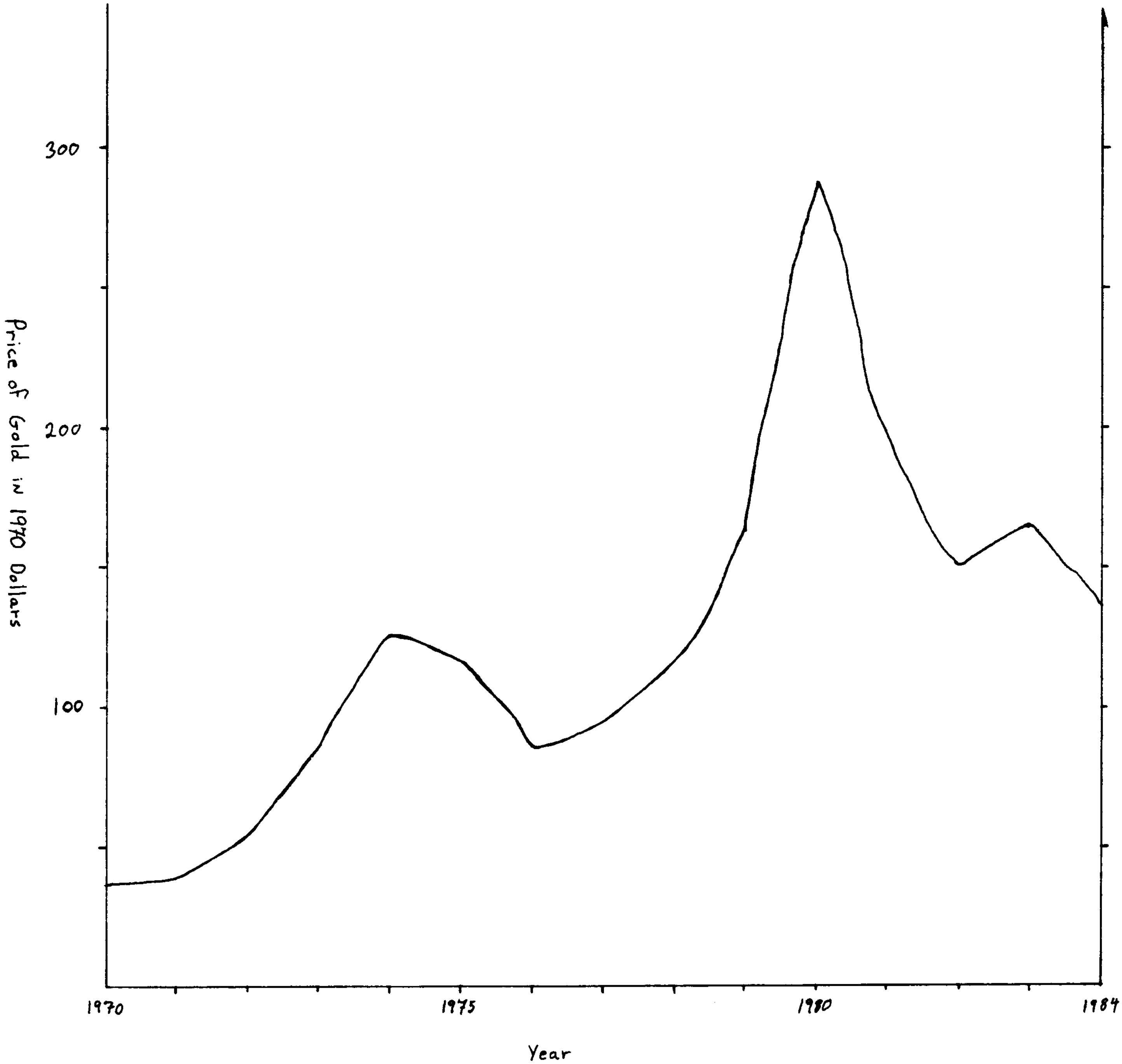

Figure 4. Adjusted Price of Domestic Gold in 1970 Dollars, adjusted for inflation, 1970-1984. Data from [Lucas,1985], [Lucas,1983].

SILVER

Characteristics of Silver

Silver usually occurs in scales, massive, or arborescent and wiry aggregates. Native silver often contains gold, copper, arsenic, antimony, mercury, iron, or platinum. Silver has a specific gravity of 10.5. The color of silver is silver-white to brownish-grey, and black when tarnished. At normal temperatures silver is an excellent condutor of heat and electricity. It has a melting point of [515.9 degrees C].

Silver does not occur in the native state as much as gold. The purity of silver usually is expressed by its fineness (parts per thousand). Silver occurs primarily in veins, or as finely disseminated metal of hydrothermal origin within country rock. Fifty-five silver-containing minerals have been recognized.

Uses of Silver

Silver has been used since ancient times in jewelry and art objects, as utensils, and as a monetary metal. In recent times silver has found many new uses. The largest single use of silver in 1984 was in the photographic industry, with 48 percent of total domestic production [Reese, 1985]. Photography is based almost entirely on silver-containing light-sensitive halides. Some photographic processes have been developed that do not require the use of silver, but these processes can only be used with black and white film, and the quality of the results are not as good as with silver-backed film [Drake, 1980]. Electrical and electronic products accounted for 25 percent of domestic consumption in 1984 [Reese, 1985]. Silver is a minor but essential part of most electrical appliances through its use as a contact metal in switches. Sterlingware, electroplated ware, and jewelry consumed about 11 percent of domestic production in 1984 [Reese, 1985]. Brazing alloys and solders account for 5 percent of domestic use in 1984. Brazing alloys are used in refrigeration systems because the silver alloy can withstand a wide range of termperatures. Some appliances also utilize silver solders because of its high conductivity and high resistance to oxidation. The other 11 percent of silver use in 1984 went into diversified products.

Byproducts and Coproducts of Silver

About two-thirds of the world silver reserves are considered to be a byproduct of copper, lead, and zinc deposits [Drake, 1980]. In recent years there have been cut backs in base-metal mining, which has decreased the amount of silver mined as byproduct. Many base metal mines also produce gold and silver as important coproducts.

Silver Technology

Silver exploration and mine development has increased in recent years due to the shift in emphasis from base-metal to precious metal production. Low-cost pitcyanidation and a carbon-in-pulp technique for recovering silver from old mill tailings appear to be an additional source of recoverable silver [Drake, 1980).

Advances in the photography industry have decreased the amount of silver used. Photographic fixing solutions are being recycled for reuse, and new photographic papers and films are being developed to use smaller quantities of silver. No major breakthrough in "silverless" image reproduction is currently foreseen, and to date, there is no satisfactory substitute available [Drake, 1980].

In electronics, improvements in solid-state switching, and in electroplating and cladding technology will require less silver per unit product, while increasing the expected life of the equipment. Some batteries are being developed that may replace silver batteries in some applications; however, it is likely that new types of silver-containing batteries will be developed increasing the use of silver. [Drake, 1980].

The silver in mirrors and other reflecting objects is being substituted for with aluminum and rhodium, and stainless steel has been used widely in place of silver in tableware. Cupronickle, cuprozinc, nickel, and aluminum have replaced silver in the coinage of many countries [Reese, 1985], and this trend to find substitutes for silver will increase as the price of silver climbs in the future.

Production of Silver

In recent years there has been an increasing emphasis on precious metals recovery, which has led to increased productivity from new and old mines [Reese, 1985]. Because of low base metal prices, and the decrease in base-metal mining, byproduct silver recovery was low in 1984. World mine production of silver is given in Table 2. Following a sharp decline in production in 1980 (Fig. 5), silver production has increased annually. After 1980, when silver prices peaked at 20.63 dollars per ounce, United States industrial consumption has stagnated at about 120 million ounces per year, owing partly to the efficient use of silver [Reese, 1985]. Demand for silver is expected to increase at an average rate of 2.2 percent through the year 1990 [Drake, 1980].

Since 1970, the United States generally has imported more silver than it has exported [Figs. 6 and 7]. Silver has exhibited complicated supply-demand relationships, but in the long run it should be subject to increasing demand. It is hard to predict the price of silver, and prior silver prices have proven to be very erratic [Fig.8]. Some manufacturers have encouraged more efficient use of silver when the price was high. This has caused industrial domestic silver consumption to remain constant since 1980 [Reese, 1985]. Consequently, the price of silver has remained constant. United States demand for silver in the year 2000 is forecast to be between 240 and 505

Table 2

World Silver Mine Production and Reserve Base For 1984

[Data in million troy ounces of silver]

Country	Mine Production	Reserve Base
United States	44.0	1,800
Canada	38.0	1,400
Mexico	62.0	1,400
Peru	58.0	950
Other Market Economy Countries	115.0	3,200
U.S.S.R.	48.0	1,600
Other Centrally Planned Economies	33.0	400
World Total	400.0	10,800

[Reese, 1985]

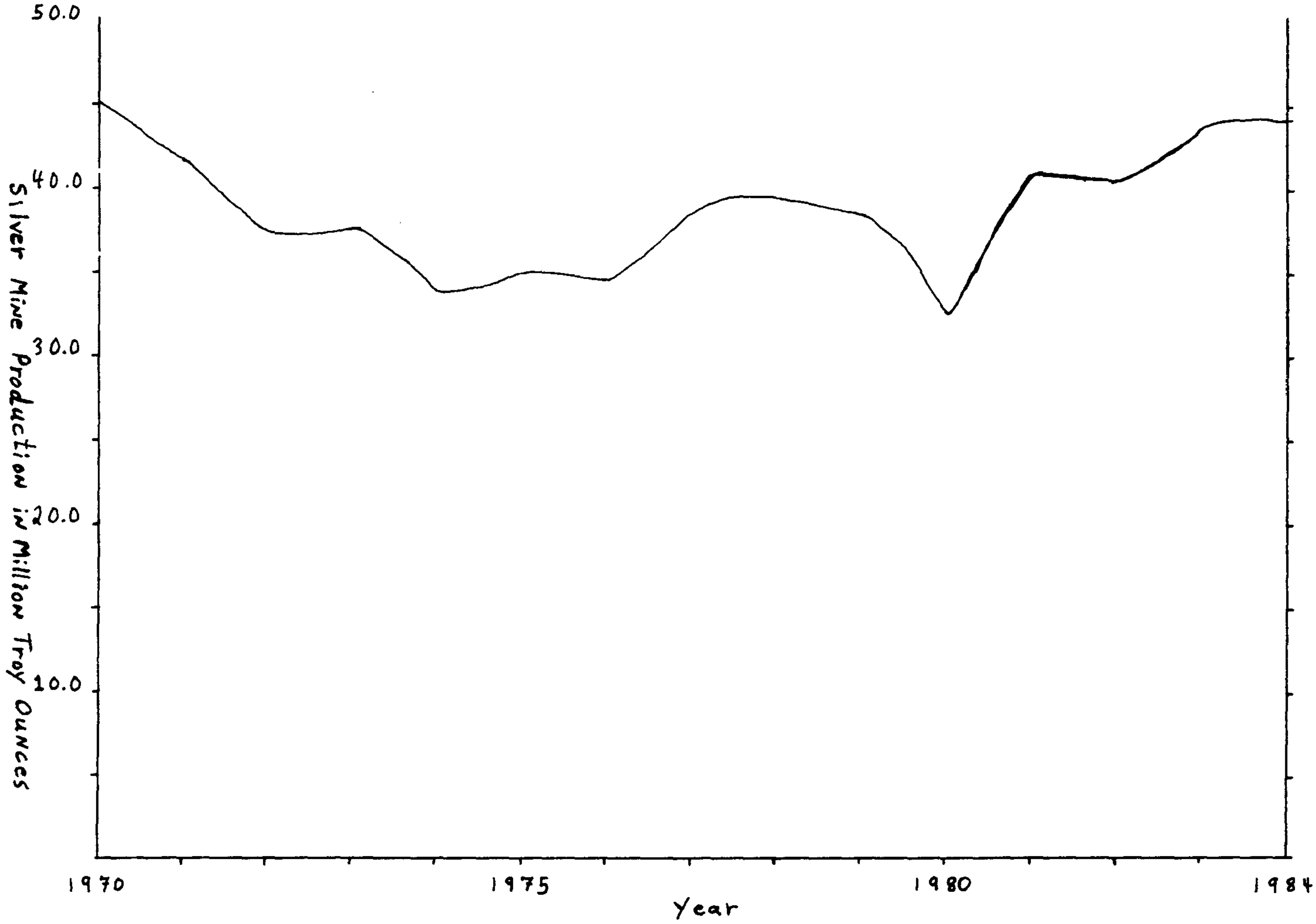

Figure 5. Total United States Silver Mine Production, actual trends, 1970-1984. Data from [Reese, 1985], [Reese, 1983].

million ounces, with a probable demand of 225 million ounces in 1990 and 310 million ounces in 2000 [Drake, 1980]. This demand represents an annual growth rate of 3.1 percent.

Silver Reserves

The reserve base for the silver reserves of the world are estimated at 10,800 million troy ounces [Table 2]. Domestic reserves of silver are 1.5 billion ounces, with the probable domestic demand to 2000 of 3.8 billion ounces, which means that the United States will depend on imports for a major part of its silver supply [Drake, 1980]. This short-fall will result in higher silver prices. On a world-wide scale, a similar situation will exist, as silver reserves are significantly below projected requirements in the year 2000.

The most significant increase in reserves is expected to come as byproduct production from base-metal discoveries. In addition, secondary recovery of silver has increased in recent years as a result of better recovery methods, which will help to alleviate the future demand for silver.

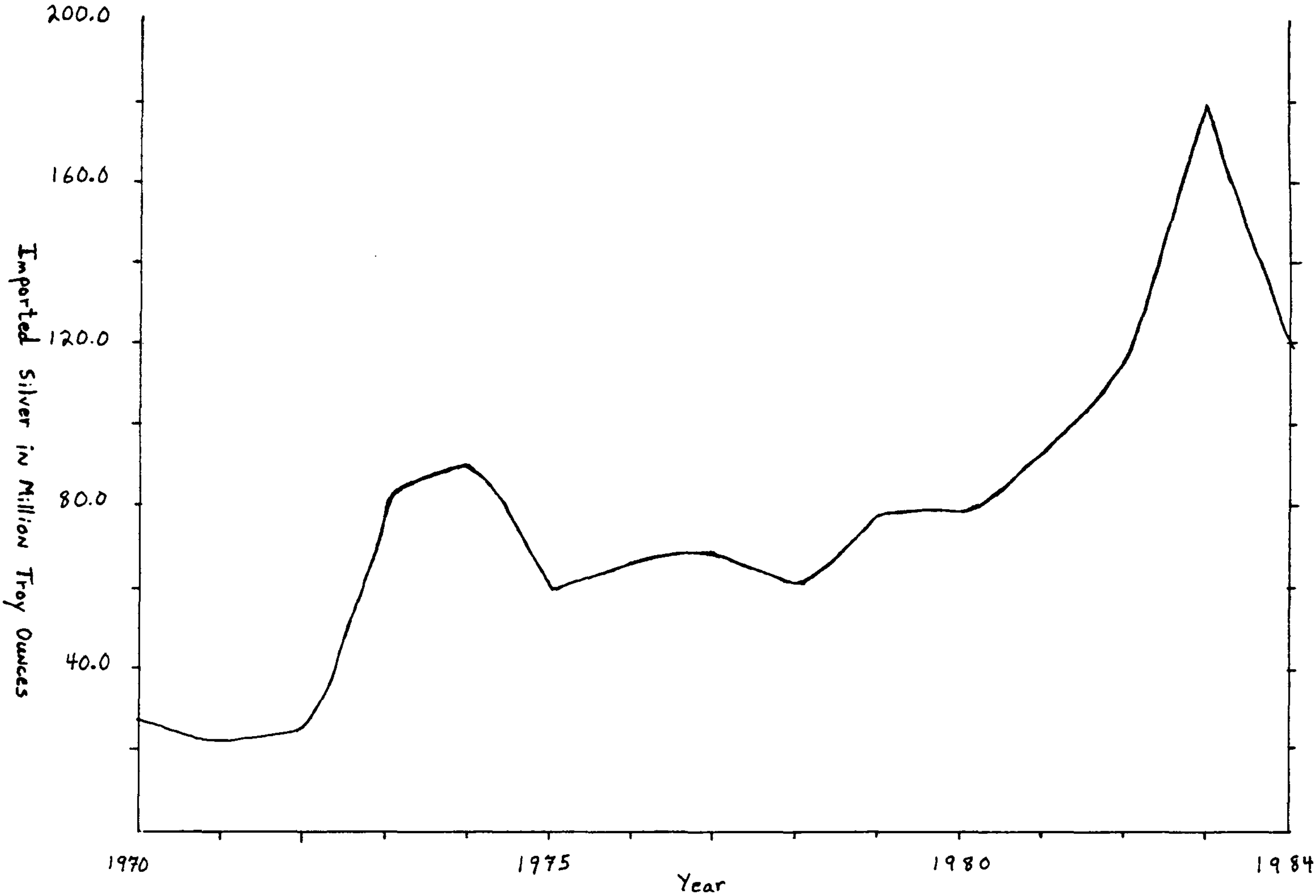

Figure 6. Total United States Imported Silver, actual trends, 1970-1984, Data from [Reese, 1985], [Reese, 1983].

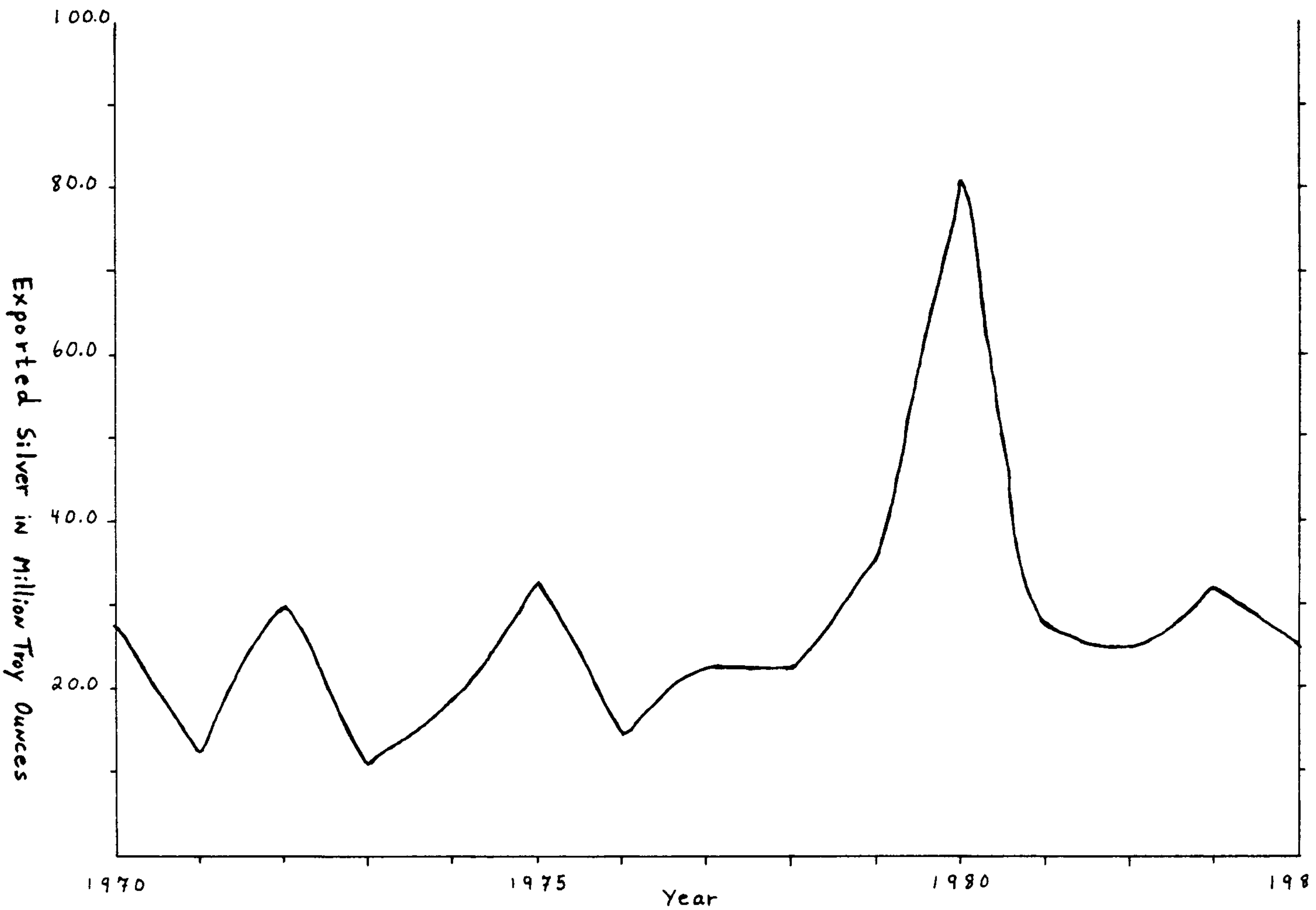

Figure 7. Total United States Exported Silver, actual trends, 1970-1984, Data from [Reese, 1985], [Reese, 1983].

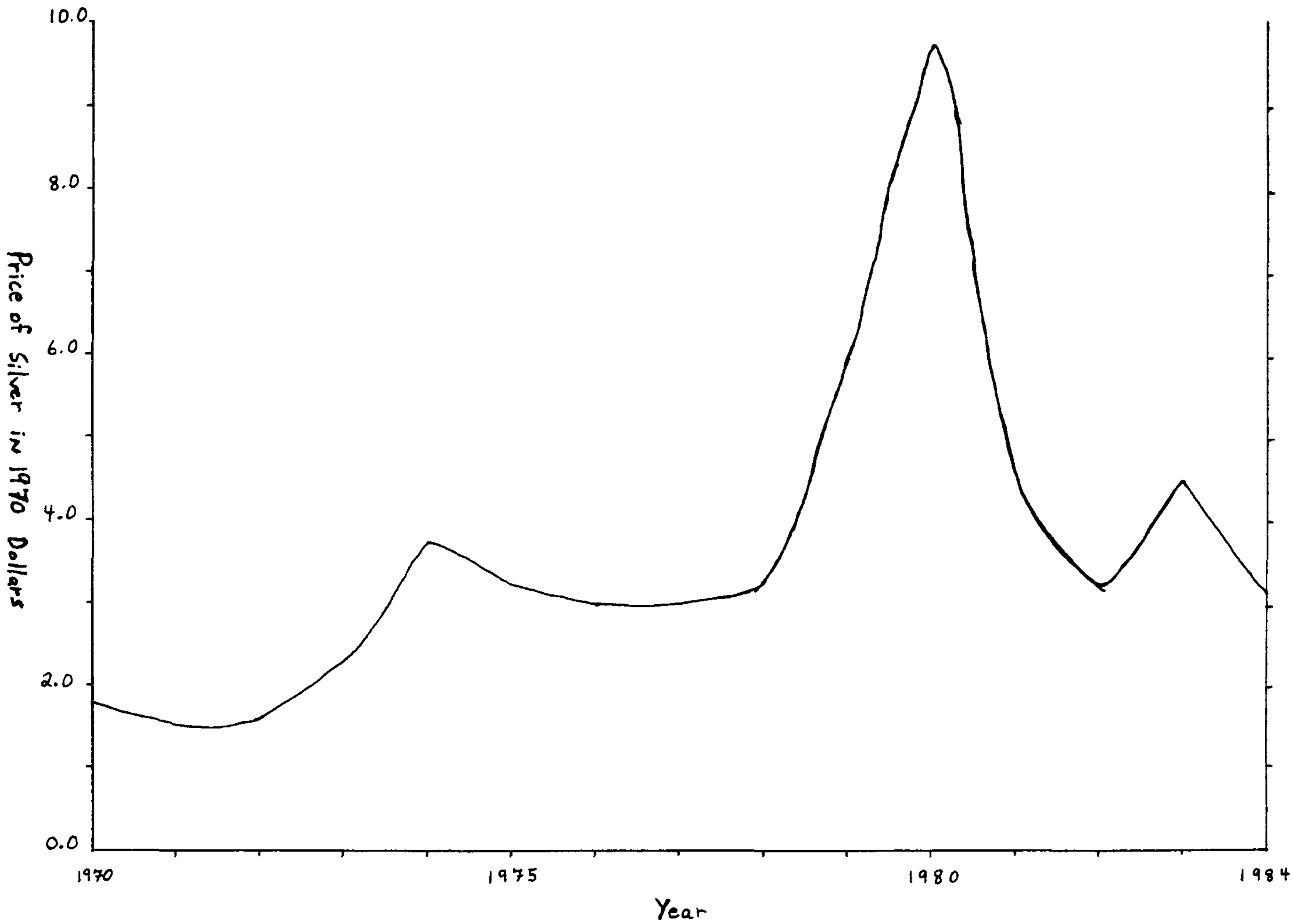

Figure 8. Adjusted Price of Domestic Silver in 1970 Dollars, adjusted for inflation, 1970-1984. Data from [Reese, 1985], [Reese, 1983].

COPPER

Characteristics of Copper

Copper generally occurs in scales, grains, plates, and masses. Native copper commonly is associated with calcite, quartz, datolite, epidote, silver, analcime, and other zeolites. To a lesser extent, copper is associated with malachite, azurite, cuprite, chalcopyrite, bornite, chalcocite, lead, zinc, and molybdenum [Ramsdell, 1959]. The specific gravity of copper ranges from 8.5 to 9.0, it has a metallic luster, it is ductile and malleable, and on a fresh surface it has a copper-red color. Copper tarnishes black, green, red, or blue. It is an excellent conductor of electricity.

Copper is classified according to the method by which it is refined. Electrolytic copper is refined by electrolytic deposition; Fire-refined copper is refined by using only a pyrometallurgical process; and electrowon copper is copper directly deposited as a cathode from a copper-bearing solution [Schoreder and Jolly, 1980]. Commercial copper can be divided into three classes according to the method of oxygen control: (1) Touch-pitch copper, which contains an oxygen content of 0.02 to 0.05 percent as cuprous oxide; (2) Oxygen-free copper, refined under a deoxidizing atmosphere that eliminates all cuprous oxide; and (3) deoxidized copper, in which the use of deoxidizers eliminates all of the cuprous oxide.

Use of Copper

Building construction, which involves roofing, plumbing, brass and bronze in decorative items consumed 34 percent of all domestic copper production in 1984 [Jolly, 1985]. Electrical and electronic products consumed 24 percent of all domestic copper. Electrical equipment like electronic motors, power generators, dynamotors, fans, and industrial controls require copper for adequate electrical performance. Electrical lighting and wiring use copper because it is a dependable, corrosion-resistant conductor of electricity. Industrial machinery and equipment accounted for 16 percent of all domestic production in 1984. Copper and copper-base alloys are resistant to corrosive environments and temperatures up to (121.1 degrees C), copper also has a high heat-transfer capability. These factors allow copper to be an important component of machinery [Schroeder and Jolly, 1980]. The transportation industry accounts for 12 percent of domestic production, with wide application in automobile construction, railroad transportation, airplane manufacture, and in marine parts. The other 14 percent of 1984 domestic production goes into consumer and general products like pigments, watches, gages, utensils, jewelry, and coinage.

Byproducts and Coproducts of Copper

Only one percent of domestic mine production of copper is recovered from complex or mixed base-metal ores; the remainder comes from ores mined primarily for copper [Schoreder and Jolly, 1980]. In addition, copper ores are the primary souce of arsenic, rhenium, selenium tellurium, platinum, and palladium, as well as significant quantities of byproducts and coproducts such as gold, silver, molybdenum, nickel, uranium, iron, lead, zinc, and sulfer [Schroeder and Jolly, 1980].

Copper Technology

Because of present trends in the copper mining industry, it appears that mine owners inevitably will be forced to strive for the greater efficiency in order to survive. Exploration, development of more efficient mining recovery techniques all will need to be advanced in the future [Schoreder and Jolly, 1980]. It also is anticipated that there will be a greater use of copper in electricity, and in other copper-related industries in the future. Increased demand also will encourage recycling of old scrap, plus exploration for new deposits. Microminaturization, copper cladding, fiber optics, and other means will be extensively used as a substitute for relatively expensive materials such as copper [Schroeder and Jolly, 1980]. Aluminum may sometimes substitute for copper in electrical equipment, automobile radiators, and refrigerator tubing; titanium and steel may substitute in heat exchangers; and steel in shell casings [Jolly, 1985].

Production of Copper

Domestic copper (mine) production in 1984 was 1.0 million tons, valued at 1.5 billion dollars. On a world-wide scale, Chile was the number one producer of copper [Table 3]. Land-based resources in 1984 are estimated at 1.6 billion tons of copper and resources in deep sea nodules at 0.7 billion tons [Jolly, 1985].

United States copper production has decreased dramatically since 1981 [Fig. 9]. Improved technology, revised production schemes and reduced labor costs have increased domestic production to a small degree from 1983 to 1984, but production has remained depressed since 1981. Six large mines either closed or curtailed production in 1984 [Jolly, 1985]. A major problem facing domestic copper producers is the sustained strength of the United States dollar in international currency markets. In addition, third world countries are able to produce copper at a cheaper price than domestic producers making it hard for United States producers to compete in international markets.

Forecasts of mine production in the United States range from 80 to 90 percent self-sufficiency related to probable primary copper demand by the year 2000 [Schroeder and Jolly, 1980]. Any deficiency in the primary copper supply will be met by imports. On a world-wide scale, primary requirements for copper will be well inside the reserve base [Table 3].

Since about 1976, the United States has been importing more copper than it exports [Figs. 10 and 11]. Imports of refined copper increased by 253 percent from 1975

Table 3

World Copper Mine Production and Reserve Base For 1984

[Data in thousand metric tons of copper]

Country	Mine Production	Reserve Base
United States	1,050	90,000
Australia	250	16,000
Canada	625	32,000
Chile	1,250	97,000
Peru	370	32,000
Philippines	250	18,000
Zaire	525	30,000
Zambia	540	34,000
Other Market Economy Countries	1,300	101,000
Poland	380	15,000
U.S.S.R.	1,000	36,000
Other Centrally Planned Economies	580	9,000
World Total	8,120	510,000

[Jolly, 1985]

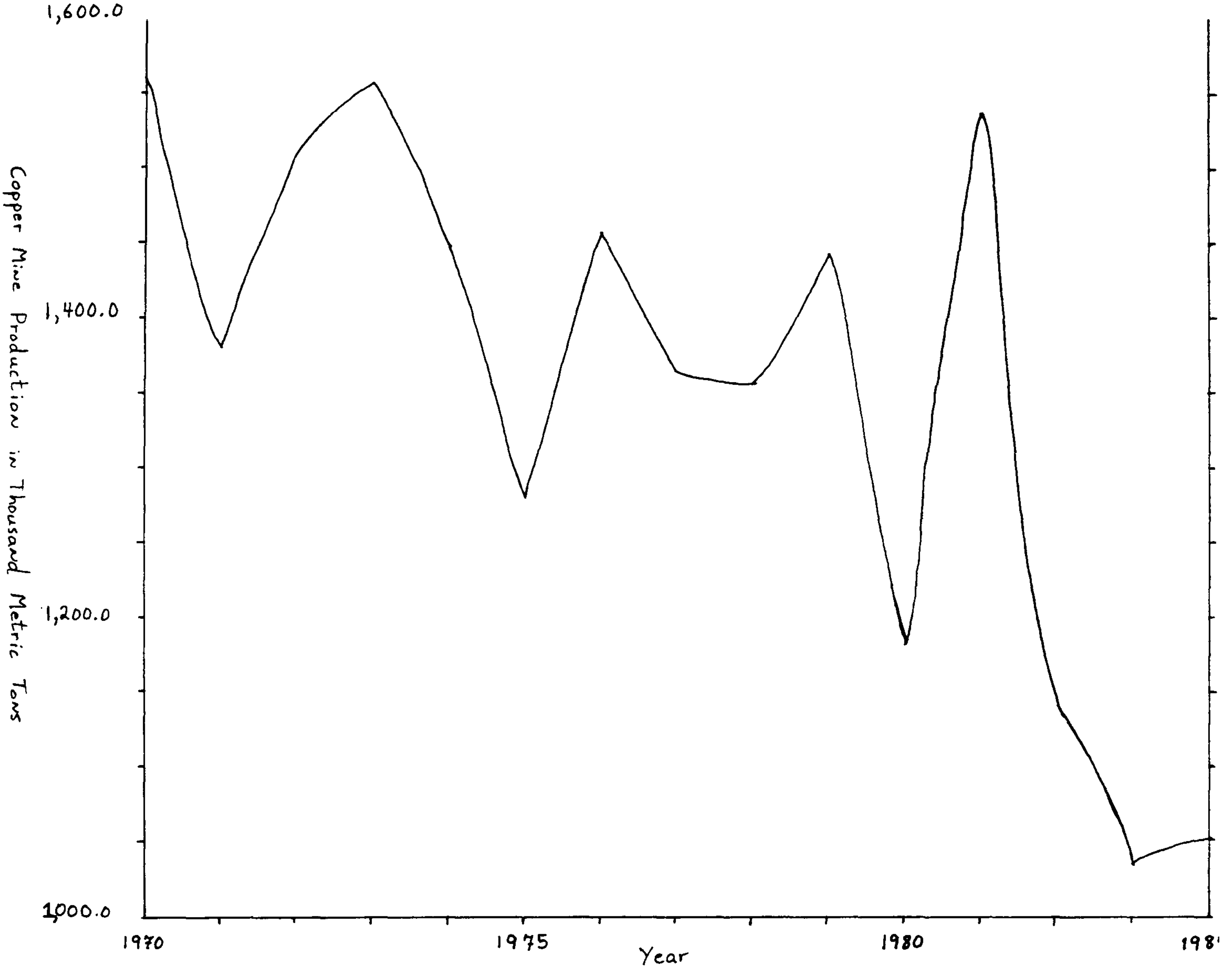

Figure 9. Total United States Copper Mine Production, actual trends, 1970-1984. Data from [Jolly, 1985], [Jolly, 1983].

to 1983, and exports decreased by 53 percent [Jolly and Edelstein, 1983]. This trend appears to be related to the availability of cheap imported copper as compared to domestically-produced metal. The domestic price of copper has decreased for the past 15 years, and the 1970 price of copper has only been exceeded once, in 1974 [Fig. 12]. In order for the United States to compete for copper in the international market, production costs must be reduced. The weighted average production cost, averaged over the life of the mine, for 15 operating domestic mines in 1984 was estimated to be 73 cents per pound [Jolly, 1985]. The average price of copper for 1984 was 66 cents per pound, so these mines were operating at a loss.

Copper Reserves

The reserve base for copper reserves in the world is estimated at 510,000 thousand metric tons [Table 3]. The United States has within its borders about 19 percent of the known world copper reserves, whereas Chile, Canada, the U.S.S.R., Zambia, Peru, and Zaire account for 60 percent of the remainder. Domestic copper reserves have been forecast to supply all of the United States' needs through the year 2000 [Schroeder and Jolly, 1980].

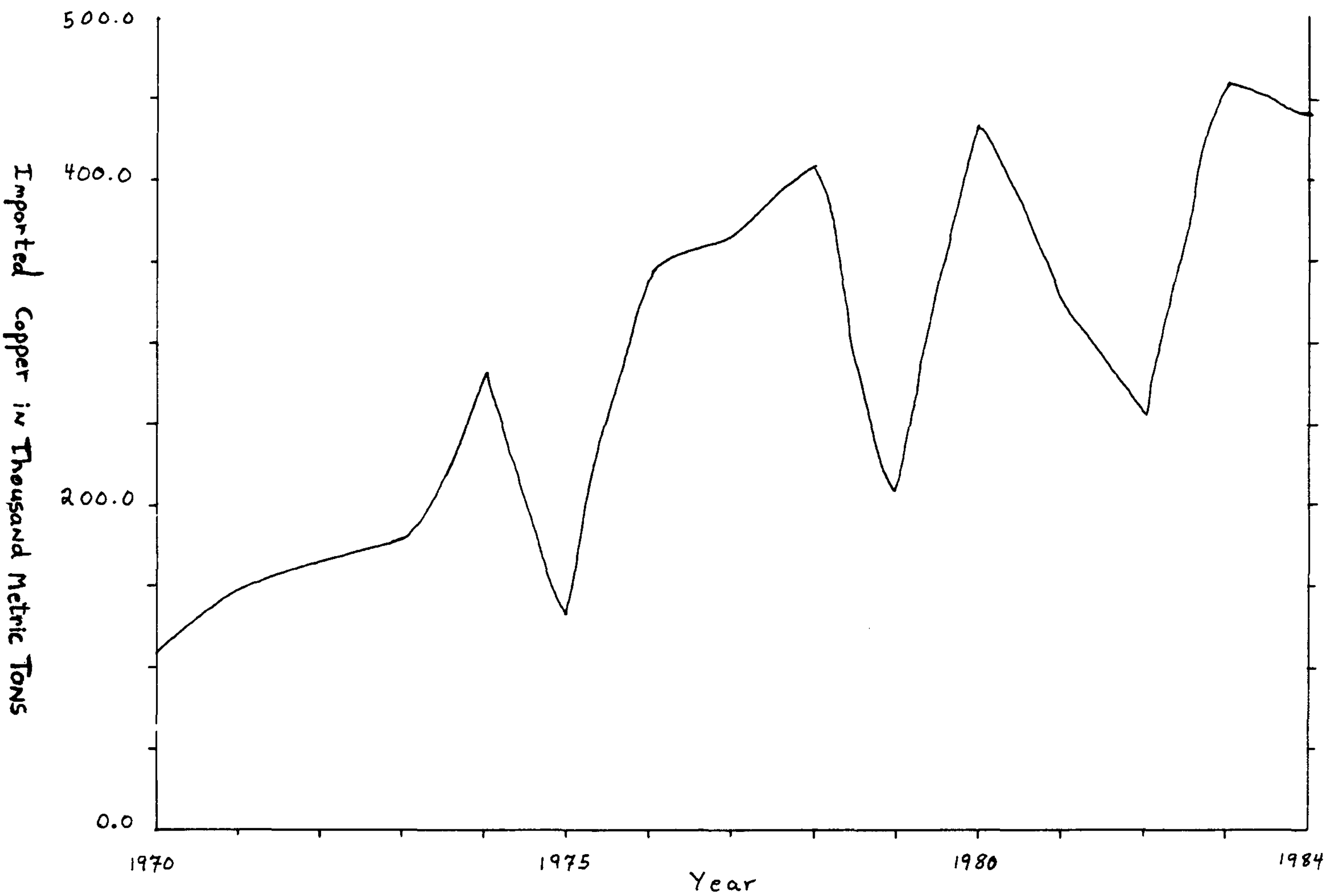

Figure 10. Total United States Imported Copper, actual trends, 1970-1984. Data from [Jolly, 1985], [Jolly, 1983].

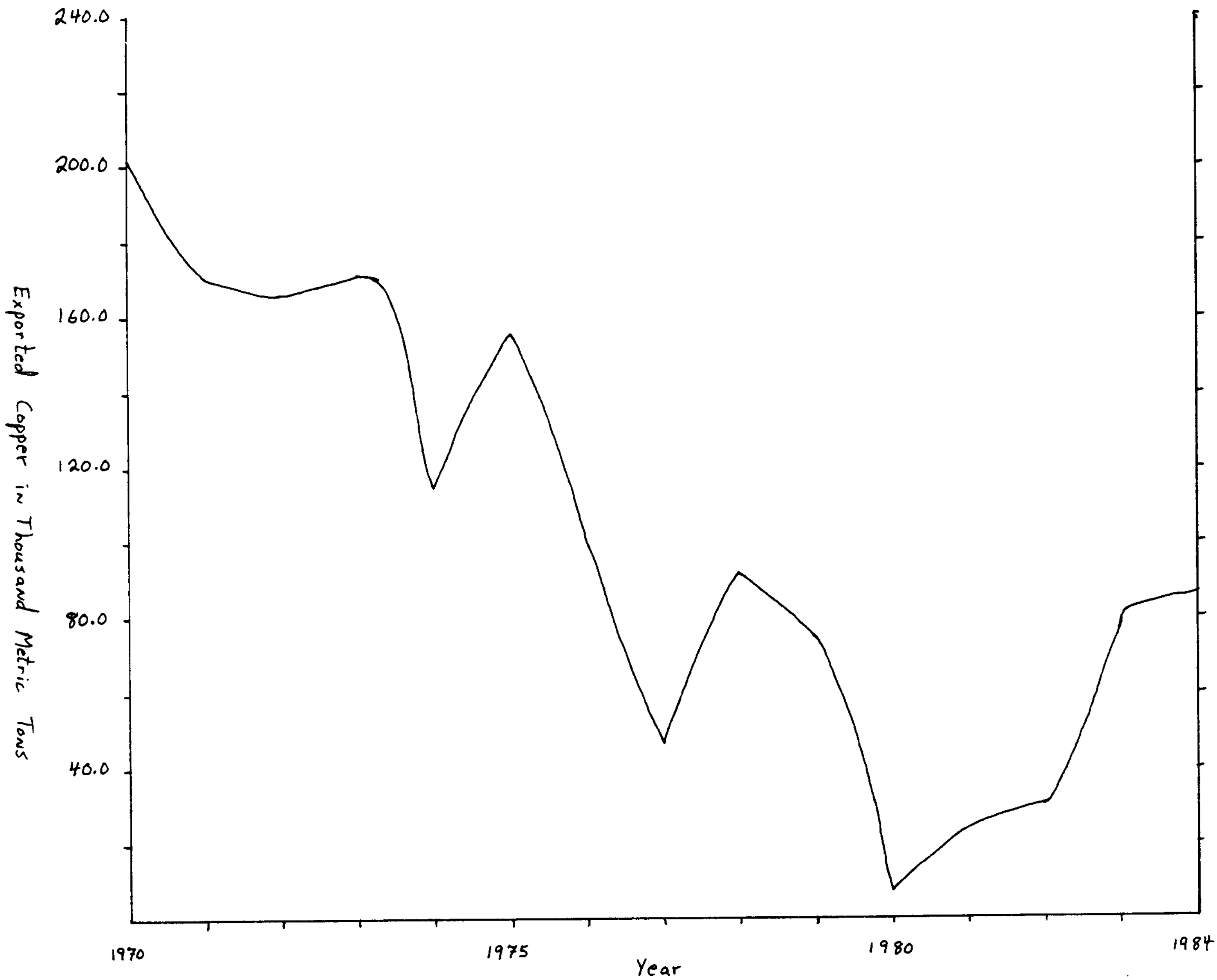

Figure 11. Total United States Exported Copper, actual trends, 1970-1984. Data from [Jolly, 1985], [Jolly, 1983].

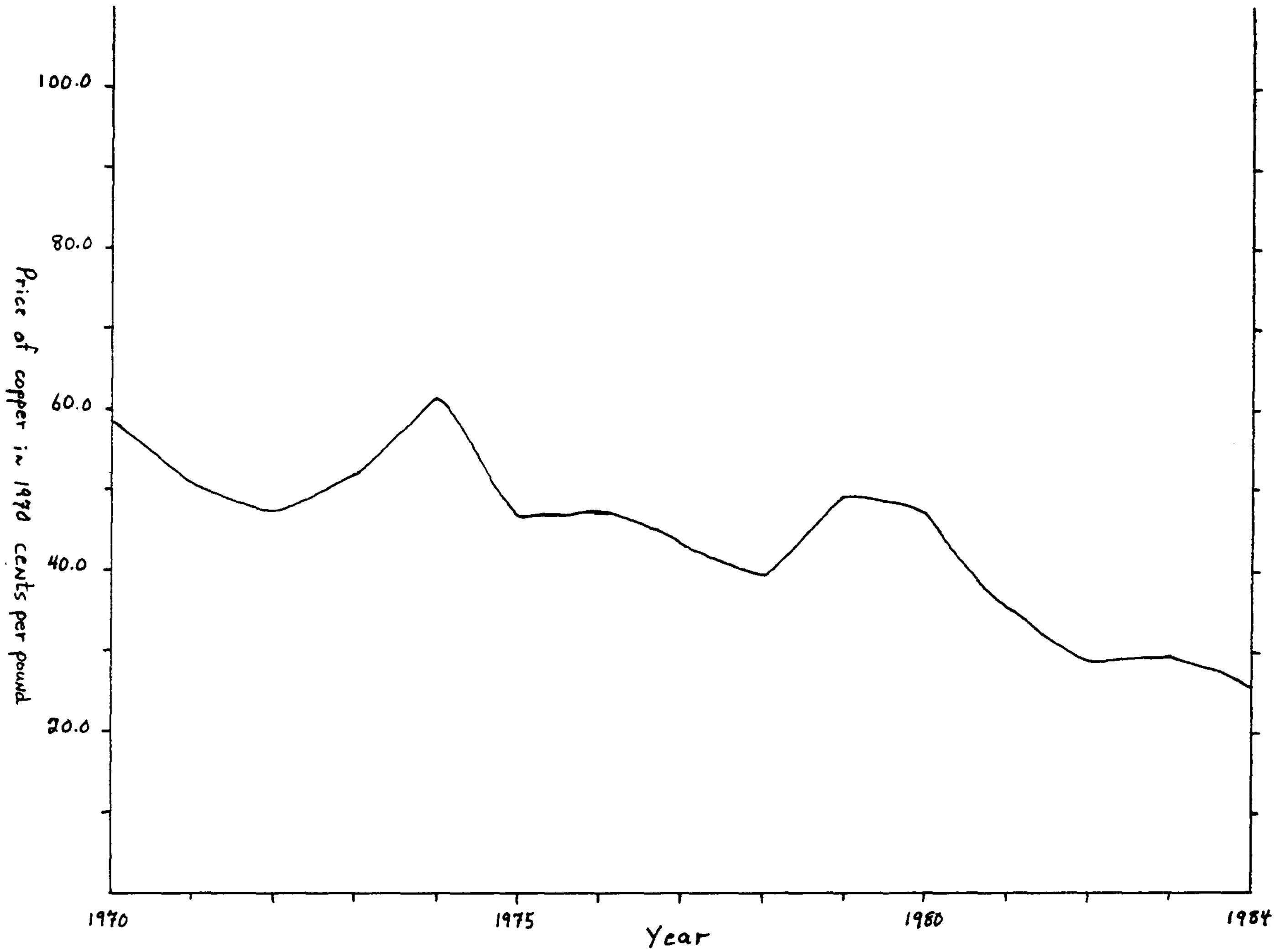

Figure 12. Adjusted Price of Domestic Copper in 1970 Dollars, adjusted for inflation, 1970-1984. Data from [Jolly, 1985], [Jolly, 1983].

MOLYBDENUM

Characteristics of Molybdenum

Molybdenum is a silver-white metallic element with an atomic weight of 95.95, atomic number of 42, and a density of 10.2 grams per cubic centimeter. The melting point of molybdenum is (2610 degrees C), and it has strong carbide-forming properties. Some of the properties are: a conductivity of about one-half that of copper; the lowest coefficient of thermal expansion of the pure metals; and high strength at elevated temperatures. In air or water, molybdenum, at moderate termperatures, will remain stable, but above about (500 degrees C), it oxidizes readily [Kummer, 1980].

Molybdenum ore is processed to concentrate the principal mineral molybdenite, and the molybdenite concentrate then is roasted to produce technical-grade molybdic oxide. Purified molybdic oxide, ferromolybdenum, ammonium and sodium molybdate, and molybdenum metal power are produced from the molybdic oxide [Kummer, 1980].

Uses of Molybdenum

About three-fourths of the molybdenum produced is in the iron and steel industry, which accounted for about 75 percent of domestic molybdenum production in 1984 [Blossom, 1985]. The remaining 25 percent went into the production of intermediate products such as ferromolybdenum, metal powder, and various chemicals. Molybdenum is used as an alloy in steels to obtain a variety of desired physical properties: improved toughness; increased resistance to temper embrittlement, abrasion, and corrosion; and enhanced hardness and strength, at elevated temperatures. The principal nonmetallurgical applications, of molybdenum are in lubricants, catalysts and pigments. As a lubricant, molybedenum is preferable to graphite, especially for high-pressure work. Molybdenum is widely used as an additive to oils and greases, in aerosal sprays applied to reduce surface friction, and in plastic and metal composites as an antiwear or antifriction agent [Kummer, 1980].

Petroleum-refining processes incorporate molybdenum as a catalyst for hydrotreating and desulfurization of oil. Reactions that produce alcohols, formaldehyde, and petroleum-based chemicals use molybdenum catalysts to create oxidation-reduction reactions. Molybdenum chemicals are widely used in dyes, inks, and corrosion-resistant primers [Kummer, 1980]. Chemically, molybdenum also is used as a flame retardant and smoke suppressant [Kummer, 1980].

Byproducts and Coproducts of Molybdenum

Byproducts of molybdenum mining are tin, tungsten, and minor quantities of Rhenium. Molybdenum, in turn, is recovered as a byproduct primarily from the processing of copper ores. Small amounts also are obtained from processing of tungsten and uranium ores. Copper and molybdenum are coproducts in some geologic environments (e.g. porphyry ore deposits) [Kummer, 1980].

Molybdenum Technology

Because of the versatility and availability of molybdenum, industry has sought to develop new alloys for the metal, which is expected to increase the demand for molybdenum. Metallurgical developments include corrosion-resistant ferritic stainless steels; a construction steel that combines high strength and resistance to sulfide stress cracking; Nickel-based alloys with 7 to 15 percent molybdenum that exhibit high strength and superior corrosion resistance; an low-concentration, high strength chromium-molybdenum rail steel; dual-phase, low-alloy steels with high strength and low weight; and carburizing steels with high hardenability and strength at lowered cost [Kummer, 1980].

Recovery of molybdenum from mines has been improved through the floatation process, where nitrogen was substituted for air to improve the separation of molybdenum from impurities [Fong, 1982]; and the development of electroxidation processes to recover molybdenum and rhenium from (very) low grade concentrates [Kummer, 1980].

There are many possible uses for molybdenum in the area of nonmetallurgical applications of molybdenum, because of desireable properties of the metal. Industrial research has concentrated on finding new applications of the metal as a catalyst, lubricant, corrosion inhibitor, and flame and smoke retardent.

Production of Molybdenum

In 1984, 99 million pounds of domestic molybdenum, valued at 337 million dollars, was produced by 13 firms. World production of molybdenum is estimated at 204 million pounds [Table 4]. At the present time, the known resources of molybdenum in the United States amount to 19 billion pounds, and the number increases to 46 billion pounds world wide [Blossom, 1985]. From 1975 to 1980 molybdenum production in the United States increased from 105,980 thousand pounds to 150,686 thousand pounds [Fig. 13]. After 1980 molybdenum production decreased to 33,951 thousand pounds in 1983. In 1984, domestic molybdenum production increased 192 percent, demand increased by about 25 percent, and exports increased by about 15 percent from 1983 [Blossom, 1985].

World wide molybdenum mine production has exceeded demand, and this over-supply situation is restraining the recovery of the molybdenum market. However, the market is expected to become more stable as a result of efforts by major producers to hold production and

Table 4

World Molybdenum Production and Reserve Base For 1984

[Data in thousand pounds of molybdenum]

Country	Mine Production	Reserve Base
United States	99,000	11,800,000
Canada	18,000	2,000,000
Chile	35,300	5,400,000
Mexico	13,300	500,000
Peru	7,000	500,000
Other Market Economy Countries	1,300	580,000
Centrally Planned Economies	30,000	5,170,000
World Total	204,000	25,950,000

[Blossom, 1985]

Figure 13. Total United States Molybdenum Mine Production, actual trends, 1970-1984. Data From [Blossom, 1985], [Blossom, 1983].

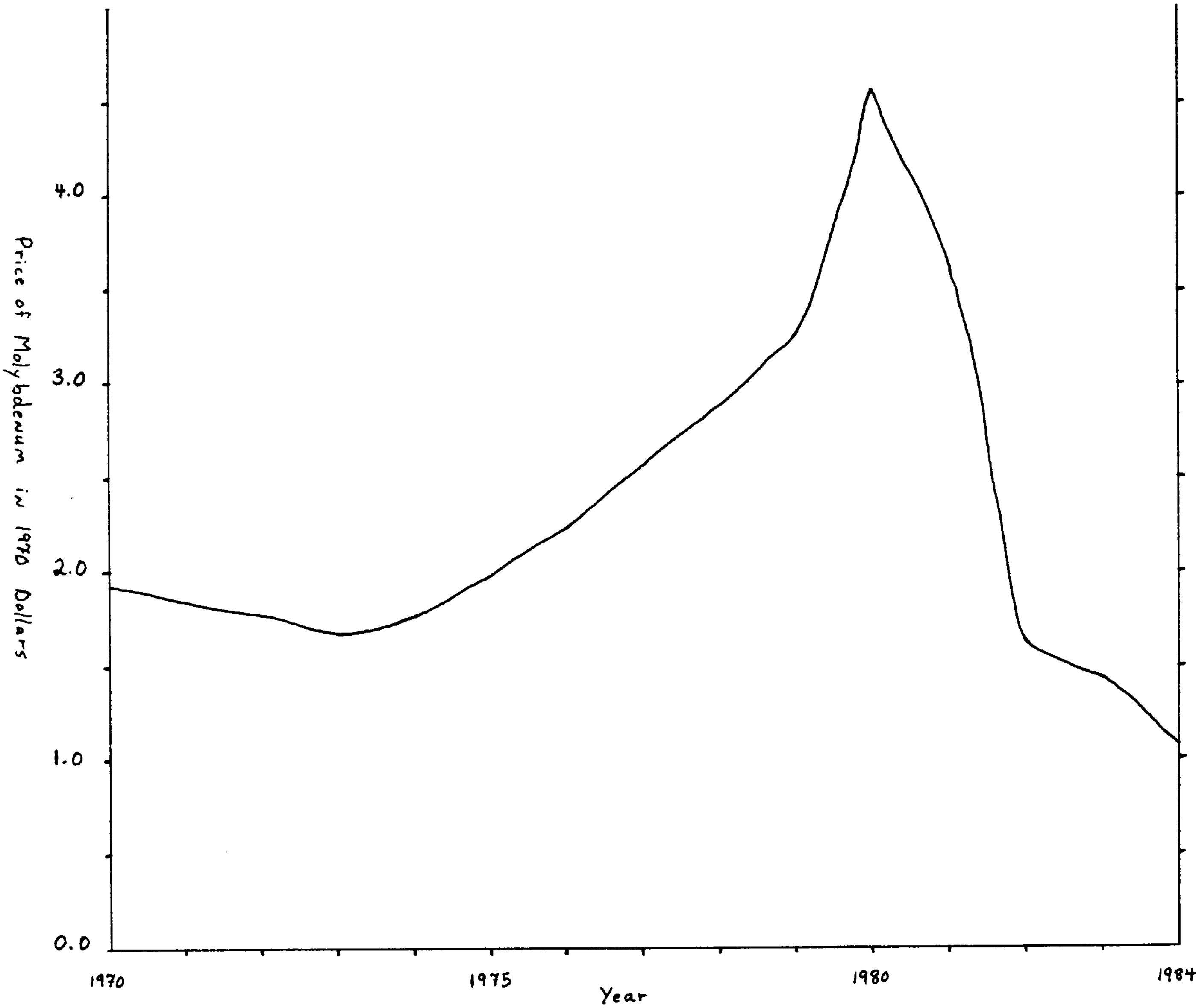

Figure 14. Adjusted Price of Domestic Molybdenum Mine Production, adjusted for inflation, 1970-1984, Data from [Blossom,1985], [Blosson,1983].

inventories at levels that are consistent with demand [Fong, 1982]. Since 1980, when the price of molybdenum was 9.70 dollars per pound, the price of molybdenum has dropped to the 1984 price of 3.40 dollars per pound [Fig. 14]. In the long run, prices are forecast to increase because of rising costs of molybdenum.

From 1979 to 1983, the United States dramatically reduced exports of molybdenum (from 74,211 to 47, 068 thousand pounds) [Fig. 15]. However, since 1983, molybdenum exports have increased to 54,000 thousand pounds, which may indicate improvement in the market. The amount of molybdenum imported into the United States has dropped to almost zero [Fig. 16], which reflects the over-supply situation within the United States.

Reserves and Resources of Molybdenum

The reserve base for molybdenum in the world is restimated at 25,950,000 thousand pounds [Table 4]. Identified resources of molybdenum amount to about 19 billion pounds in the United States and about 46 billion pounds in the world [Blossom, 1985]. Domestic demand for molybdenum is expected to increase at an annual rate of 0.8 percent through 1990. Demand for the rest of the world should increase at a higher rate, perhaps 3.3 percent, because of industrialization of developing nations. Shortages in the supply of molybdenum exploration and development will increase to meet the demand.

Figure 15. Total United States Exported Molybdenum, actual trends, 1970-1984. Data from [Blossom, 1985], [Blossom, 1983].

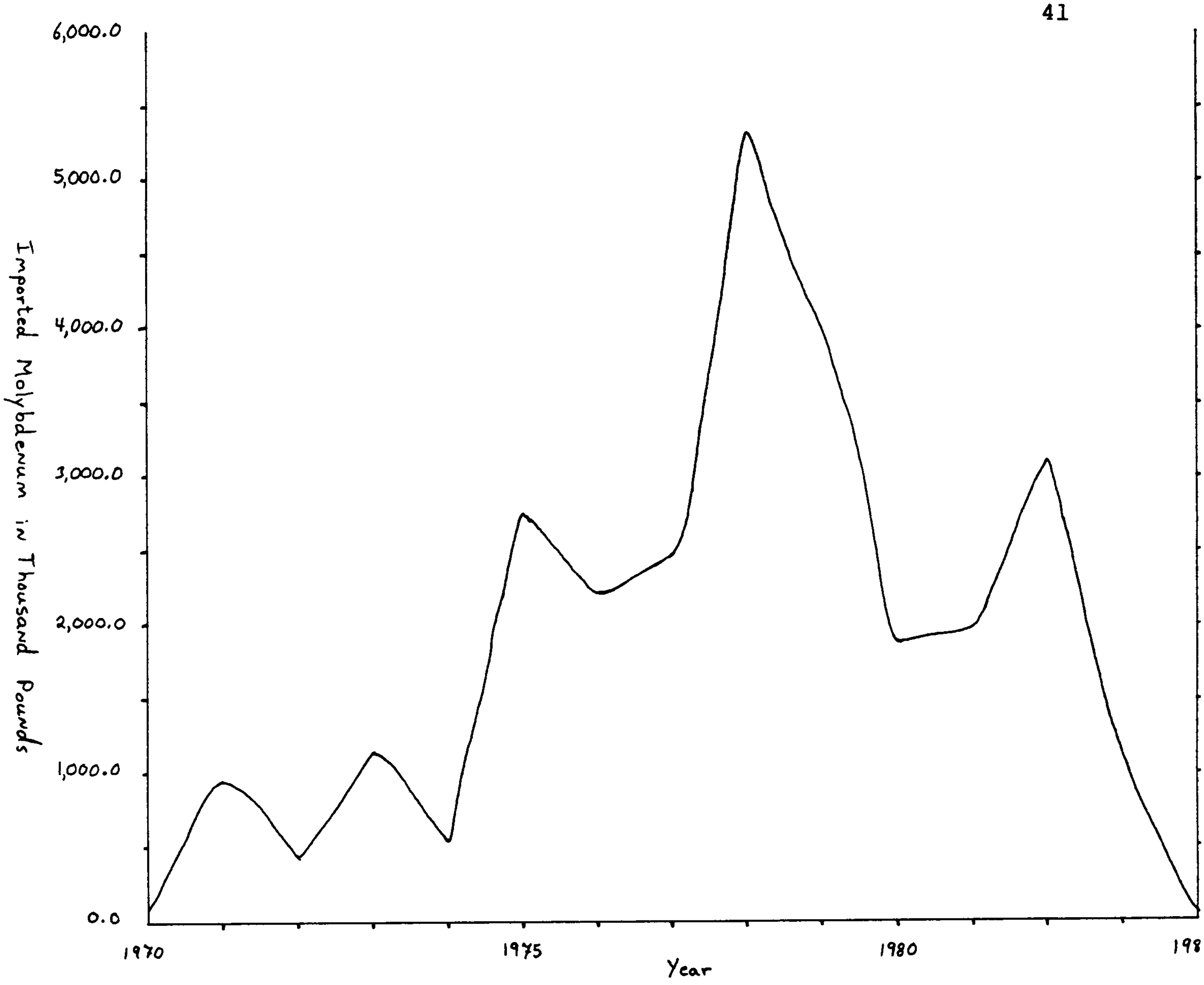

Figure 16. Total United States Imported Molybdenum, actual trends, 1970-1984. Data From [Blossom,1985], [Blossom, 1983].

ECONOMIC COMPARISON OF GOLD-SILVER AND COPPER-MOLYBDENUM

The precious metals gold and silver have been marked by increased productivity levels, as many domestic mining companies are putting more emphasis on precious metal mining. The base-metals have been characterized by decreased productivity and increased precious metal recovery from 1975 to 1984. In the future, it is forecast that demand for base-metals as well as for precious metals will increase.

At the present time production exceeds demand for most base-metals, and demand is expected to be met domestically through the year 2000. However, due to the limited resources of precious metals, productivity is forecast to be exceeded by demand by the year 2000. The base-metals industry has been market by decreasing metal values. Domestic mine production has been hurt by the ability of third world countries to produce base metals at costs that are below those in the United States. Precious metal values probably will continue to rise over the long term. As domestic productivity decreases, post 2000, the United States will have to rely more heavily on imports, and the price will increase, perhaps dramatically.

CONCLUSION

The economics of metals is essentially based on the need in society for metals, and the availability of the metals. Gold, silver, copper, and molybdenum are an important part of everyday life, and as such form an essential part of the world mineral economy. These metals have a wide range of uses today, and the growth of technology in the world constantly is defining new applications. In the United States, the mining of copper and molybdenum is experiencing difficulty because of over supply and increasing competition from countries that can produce the metals very cheaply. On the other hand, domestic mining of gold and silver has taken a turn toward increased production and the exploration for new reserves. The United States has adequate reserves of copper and molybdenum to last into the foreseeable future; but domestic gold and silver reserves probably will not be adequate, and thus the United States will continue to be a net importer of the two metals, in the foreseeable future.

REFERENCES

Blossom, J. W., 1983, Mineral Commodity summaries, "Molybdenum," United States Department of the Interior, pp. 104-105.

Blossom, J. W., 1983, Minerals Yearbook, Metals & Minerals, "Molybdenum," U. S. Government Printing Office, Washington, D.C., Vol. 1, pp. 623-630.

Butterman, W. C., 1980, Mineral Facts and Problems, "Gold", U. S. Government Printing office, Washington, D.C., pp. 367-381.

Drake, H. J., 1980, Mineral Facts and Problems, "Silver", U. S. Government Printing Office, Washington, D.C., pp. 823-835.

Emmons, W. H., 1974, Gold Deposits of the World, pp. 1-35-.

Fong, D. G., 1982, Canadian Minerals Yearkbook, 1982, "Molybdenum", Canadian Government Publishing Centre, Ottawa, pp. 29.1-29.8.

Hamilton, S. A., 1982, Canadian Minerals Yearbook, 1982, "Gold", Canadian Government Publishing Centre, Ottawa, pp. 19.1-19.19.

Jolly, L. W., and Edelstein, D. L., 1983, Mineral Yearbook, Metals and Minerals, "Copper", Vol. 1, U. S. Government Printing Office, Washington, D.C., pp. 277-319.

Jolly, L. W., 1983, Mineral Commodity Summaries, "Copper", United States Department of the Interior, pp. 40-41.

Kummer, J. T., 1980, Mineral Facts and Problems, "Molybdenum", U. S. Government Printing Office, Washington, D. C., pp. 591-609.

Lucas, J. M., 1983, Mineral Commodity Summaries, "Gold", United States Department of the Interior, p. 609.

Lucas, J. M., 1983, Minerals Yearbook, Metals and Minerals, "Gold", U. S. Government Printing office, Washington, D. C., pp. 385-411.

Ramsdell, L. S., 1939, Mineralogy an Introduction to the Study of Minerals and Crystals, Fifth edition, pp. 260-261.

Reese, R. G., Mineral Commodity Summaries, 1983, "Silver", United States Department of the Interior, pp. 140-141.

Reese, R. G., 1983, Minerals Yearbook, Metals and Minerals, "Silver", U. S. Government Printing Office, Washington, D.C., pp. 463-779.

Schroeder, H. J., and Jolly, J. H., 1980, Mineral Facts and Problems, "Copper", U. S. Government Printing Office, Washington, D. C., pp. 227-244.